10.0 MARINE ECOSYSTEMS AND SPECIES

10.1 Overview

The initial literature search on marine ecosystems and species of the Florida Keys sought peer-reviewed data on direct impacts caused by human activities in the marine environment; including propeller scarring in seagrass, boat collisions and anchoring impacts of coral, diving and snorkeling impacts, and fishing pressure. The literature search also sought information on the potential effects of nutrient, pollutant, and pathogen discharges from the Florida Keys on the water quality and benthic communities within the FKNMS. Despite the existence of an extensive and growing body of literature on the ecological resources and water quality characteristics of the FKNMS (reviewed in Porter and Porter 2002, Sullivan et. al 1996), the available data are insufficient to establish predictive relationships between land development activities and the impacts listed above. However, the test CCIAM explored the use of a simple dispersal model to estimate the Florida Keys contribution to nutrient concentrations in the FKNMS. The remainder of this section discusses available data on water quality, benthic community biological response to nutrients, and direct human impacts to marine resources in the FKNMS.

10.2 Water Quality and Benthic Communities of the Florida Keys National Marine Sanctuary

10.2.1 General Characteristics of Water Quality in the Florida Keys National Marine Sanctuary

Since 1995, EPA and the State of Florida have been monitoring water quality in the FKNMS. Boyer and Jones (2002) have summarized the results of this monitoring program based on sampling from 1995 to 1998. They concluded that, at a Keys-wide scale, the FKNMS exhibited "very good" water quality (Boyer and Jones 2002, page 613). They showed that the Upper Keys generally have lower nutrient concentrations than the Middle or Lower Keys. Concentration of TN generally decreased from inshore to offshore (both bayside and oceanside); the same occurred for TP, with the exception of the Upper Keys, where TP increased offshore, oceanside. Median TP and TN concentrations were 0.17 µm and 10.04 µm respectively, with a median TN:TP ratio of 62.10, indicating a P-limited environment (benthic organisms uptake N and P in relatively constant ratios. A P-limited environment has lower availability of P and benthic organisms may respond rapidly to increases in P). Sampling stations located in channels or passes had significantly higher nutrient concentrations than stations located off land; however, differences were "very small and not likely to be biologically important" (Boyer and Jones, op. cit., page 626).

The Nature Conservancy (TNC) has run a volunteer-based water quality sampling program in canals and other nearshore locations in the Florida Keys since 1994. Keller and Itkin (2002) have reported on the results of this program. Results based on sampling data from November 1996 to October 1997 show that monthly TN values range from 13.6 to 177.0 µm, with the largest annual mean occurring in the Upper Keys, followed by the Lower and Middle Keys.

Statistically significant differences occurred only between Upper and Middle Keys values. TN was lower in sampling stations near developed areas (41.3 µm) than in natural shorelines (52.3 µm). Monthly mean values for TP ranged from 0.17 to 5.25 µm. Annual mean was not statistically different between stations with regard to region (Upper, Middle, Lower Keys), shoreline type (developed, undeveloped), side (bayside, oceanside), or season. A significant correlation between TP and Chl *a* suggested that P-limitation occurs.

Kruczynski and McManus (2002) provide an extensive discussion of water quality issues in the Florida Keys. They reviewed TN and TP data for three canals, and show values between 19.8 and 40.5 µm for TN and between 0.21 and 1.04 for TP; both higher than those observed in open waters. Lapointe et al. (1994) also measured elevated TN and TP levels (>35 µm and >0.45 µm, respectively) at sampling stations that received direct nutrient inputs, including a canal in Big Pine Key.

10.2.2 Water Circulation

Water quality is highly influenced by circulation patterns. Lee et al. (2002) and Smith and Pitts (2002) recently reviewed the current state of knowledge regarding circulation patterns in the Florida Keys. Circulation patterns are complex and vary in space and time and exhibit influences from regional current, local gyres, tidal movements, and wind patterns. Smith and Pitts (2002) conclude that there is a clear coupling between the Gulf of Mexico and the Atlantic side of the Keys, mainly through Florida Bay and tidal channels. A diagram showing four arrows from Florida Bay across channels to the Atlantic side of the Florida Keys, represent “consistent flow direction” within the FKCCS study area (Figure 12.7 in Smith and Pitts, 2002). Despite extensive documentation of circulation patterns, the development of a hydrodynamic model for the Florida Keys has not been undertaken.

For the FKCCS, diligent attempts to adapt existing models or to develop a simple model led to the conclusion that existing models and data are insufficient. Therefore, the study team developed a simplified dispersal approach to explore the potential effect of land-generated nutrients on the water quality of the FKNMS (Section 10.2.6).

10.2.3 Pathogens in the Marine Environment

High levels of pathogens in recreational waters can increase human exposure through ingestion and body contact; therefore, increasing the risk of human illness. Total and fecal coliform bacteria are frequently used as indicators for waters polluted by human wastes typically through sewage and stormwater runoff. Additionally, other agencies recommend other indicators for use in marine waters, such as Enterococci. A review of federal, state and local datasets revealed that, while several programs are in place (Table 10.1), no long-term data were available to establish a relationship between land development and human pathogens in the marine environment in the Florida Keys.

10.2.4 <u>Effects of Nutrients on Benthic Communities</u>

The literature review focused on finding peer-reviewed documentation of the relationship of land development activities and the distribution, extent, and ecological conditions of benthic communities in the Florida Keys. In particular, efforts focused on the documentation of the relationship between water quality and benthic communities.

The primary GIS data available for benthic communities is the FKNMS Benthic GIS data layer (FMRI 2000), which shows the distribution and extent of benthic communities in the FKNMS (Figure 10.1 and Table 10.2).

An extensive body of literature explores the effects of pollution on seagrasses, but even widespread agreement on the appropriate indicator to study is elusive. Short (1987) recognized the difficulty in sorting through many interactive factors in order to isolate the effect of any one factor. Durako (1995) suggested that short shoot density may be very useful as an indicator of trends, because of its relation to mortality and recruitment within a population. But Hall et al. (1991) had indicated that short shoot density may be limited to indicating chronic effects because of its slow response to stress. Tomasko and Lapointe (1991) investigated shoot density, biomass, blade turnover rates, and epiphyte levels as indicators of effect, while Tomasko et al. (1996) used aerial blade biomass and short shoot density, and Lapointe et al. (1994) examined shoot biomass, epiphytes, and macroalgal biomass.

Phytoplankton or chlorophyll *a* levels in the water column may serve as useful indicators, because these parameters relate to nutrient pollution-induced light attenuation in the water column. Many authors have documented the effects of light penetration on seagrass populations (e.g., den Hartog and Polderman 1975, Orth and Moore 1983, Wetzel and Penhale 1983, Dennison 1987, 1990, Dawes and Tomasko 1988, Kenworthy et al. 1990, Giesen et al. 1990, Onuf 1990, Hall et al. 1990, Duarte 1991, and Stumpf et al. 1999). One of the factors affecting light attenuation is the density of phytoplankton suspended in the water and absorbing the light energy. Because phytoplankton growth is a function of nutrient levels in the water, it is often an indicator of eutrophication (Lapointe and Clark 1992, Duarte 1995, Avery 1996, Boynton et al. 1996, Bricker and Stevenson 1996, Johansson 1996, Hall et al. 1999). Epiphyte growth, which may interfere with seagrass photosynthesis, also relates to nutrient input (Sand-Jensen 1977, Silberstein et al. 1986, Tomasko and Lapointe 1991, Frankovich and Fourqurean 1997).

While these phenomena are rather well understood qualitatively, their quantitative relationships are less clear. Livingston (2000, page 4) stated: “Despite a plethora of studies…the processes involved in nutrient loading that ultimately lead to altered phytoplankton populations and associated food web changes remain largely undefined.” Indeed, Boyer (1997) defined several “zones of similar influence” in Florida Bay where nutrient dynamics likely differ by zone, and as recently as 1997, some scientists were proposing studies to determine the most effective protocol for assessing the ecological condition of seagrass populations (Durako et al. 1997).

TABLE 10.1
PROGRAMS THAT ADDRESS PATHOGENS IN THE MARINE ENVIRONMENT IN THE FLORIDA KEYS

Agency	Program	Parameters	References and Notes
Federal			
USEPA	Recreational water standards	Total and fecal coliforms	Henry and Heinkie 1996
	Recreational – Marine	Enterococci	Griffin et al. 1999
	Beach Watch Program	A national health survey of beaches	http://www.epa.gov/ost/beaches/ No data available for Monroe County.
	STORET Database	Surface and groundwater data	http://www.epa.gov/storet/
	Bacteriological Ambient Water Quality Criteria for Marine and Fresh Recreational Waters	E. coli	"EPA believes that the newly recommended indicators are superior to the fecal coliform group… [and] EPA strongly recommends that states begin the transition process to the new indicators. …only enterococci is recommended for marine waters." (USEPA 1996)
		Enterococci	
		Total coliforms	
USEPA/FKNMS	Florida Keys Water Quality Protection Program	Physio-chemical parameters:	www.fknms.noaa.gov One facet of Southeastern Research Center Water Quality Monitoring Network.
		Nutrients (including Nitrogen and Phosphorous).	
		Biological parameters: fecal coliform bacteria	
State			
DEP	305b, Surface Water Ambient Monitoring Program	Watershed monitoring	Measured in USGS hydrologic units corresponding to major surface water drainage basins.
Florida Department of Health	Healthy Beaches Program	Fecal coliform	http://www.epa.gov/ost/beaches/beachlinks.html
		Enterococci	
	Ambient water quality standards	Total coliforms	Griffin et.al. 1999
		Fecal coliforms	
Local			
Monroe County Health Department		Fecal coliform	Rate beaches with a "poor" or "good" status
		Enterococci	
Other Studies			
University of South Florida	Department of Marine Sciences	Clostridum spp.	Better indicator for tropical waters (Griffin et al. 1999)
Mote Marine Laboratory	Technical Report No. 396	Coprostanol, tested sediment as an indicator of municipal sewage contamination	

Notes:

19 facilities actively discharging into Sanctuary waters including 10 WWTP. (FKNMS 1996)
Industrial discharges include Stock Island and Marathon's desalination units. (EPA 1993)
Domestic wastewater is the most important indirect polluter. (EPA 1992)
There are 30,000 septic tanks and cesspits in the Keys. (EPA 1992)
Florida Keys are Class II Waters and Outstanding Florida Waters. (FAC 62-302)

FIGURE 10.1
EXAMPLE OF BENTHIC COMMUNITIES GIS LAYER FROM FMRI

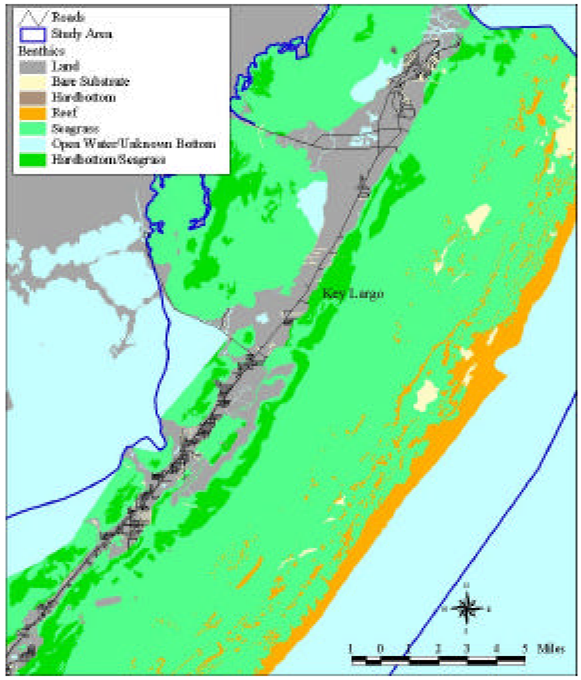


TABLE 10.2
FKNMS BENTHIC HABITAT TYPES

Habitat types	Description
Coral Reef	Patch reefs; Platform Margin Reef; Coral Patches in Bare Sand; Back Reef; Reef Rubble
Hardbottom (Inshore only, stops at Hawk Channel fo r FKNMS)	Soft Coral, Hard Coral, Sponge, Algae; Hardbottom with perceptible seagrass (<50 percent)
Bare Substrate	Carbonate Sand; Carbonate Mud; Organic Mud
Seagrass	Moderate to Dense, continuous beds; Moderate to Dense, nearly continuous beds (seagrass>50 percent); Sparse, continuous beds; Patchy
Miscellaneous	Tidal creeks
Special Modifiers	Banks; Dredged/Excavation; Venetian Canals; Restoration
Unmappable/Uninterpretable	Beyond the depth threshold of aerial photography (approximately 30 ft), and/or uninterpretable due to glare, or turbid waters. Most narrow or deep access channels such as Key West Harbor, Hawk Channel, or deeper sides of the reef tract.

Different opinions remain regarding which parameters are most meaningful to measure nutrient input. Varying approaches and measurements address the relationship between nutrients and seagrasses. Significant studies frequently involve different input parameters. For example, Tomasko and Lapointe (1991) and Stevenson *et al.* (1993) examined correlations between dissolved inorganic nitrogen (DIN) and impacts on seagrasses, while Tomasko (1996) and Lapointe (1994) measured TN in assessing impacts. Similarly, Tomasko and Lapointe (1991) examined effect correlations against soluble reactive phosphorous (SRP), while Lapointe (1994) measured effects against TP, and Stevenson (1993) used mean dissolved phosphate.

Lapointe et al. (1994) determined that TN and TP concentrations decreased with increasing distance from shore. They measured TN and TP concentrations in the water column as well as seagrass productivity parameters. They concluded that the use of TN and TP pools appears to be the best single nutrient index of eutrophication as this measurement includes all nutrient pools and is also a proxy for water transparency (Lapointe and Clark 1992). Therefore, the FKCCS explored the connections between TN and TP loads and their contribution to TN and TP concentrations in the marine environment.

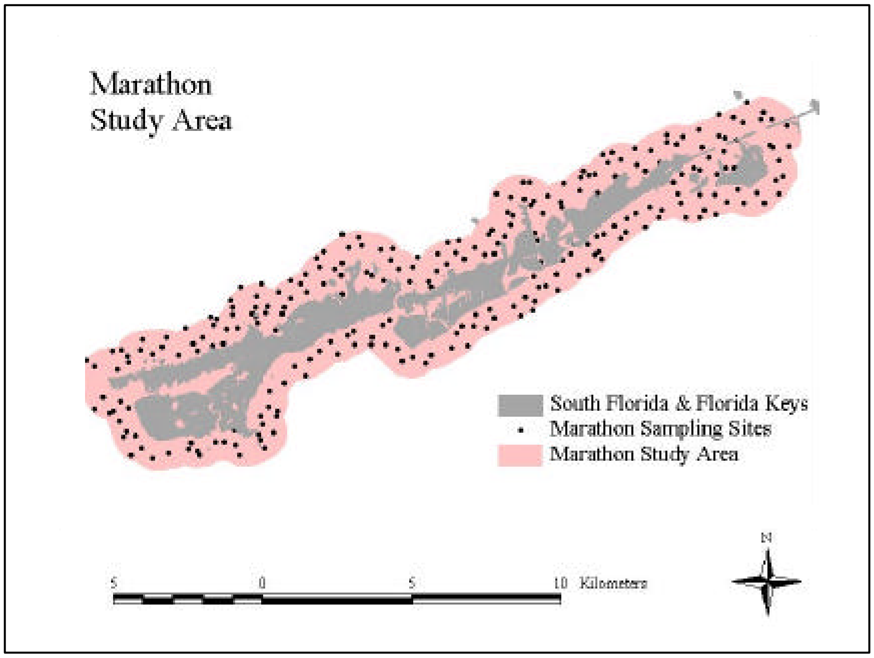
10.2.5 Field Survey to Investigate Benthic Variations in the Nearshore Environment

The FKCCS included an investigation by Florida International University (Jim Fourqurean and Leanne Miller-Rutten investigators) of nearshore (<1 km from shore) benthic communities of the Florida Keys (Appendix A). This study was a departure from the general FKCCS effort in that it sought new data; the project sponsors took advantage of the fact the FIU had already designed the study, including a scope of work and available researchers. The study addressed a key aspect of the relationship between land development and benthic communities. The study tried to identify spatial and temporal variations within nearshore benthic communities and their associated nutrient regimes and to determine if these variations may be associated with human land use activity in the Florida Keys. Working hypotheses included:

- **H_1:** Nearshore benthic communities and their associated nutrient regimes exhibit spatial/temporal variation throughout the Florida Keys.
- **H_2:** There is a significant relationship between human land use activity and spatial/temporal variation of nearshore benthic communities and their associated nutrient regimes throughout the Florida Keys.

The project began with the creation of maps of the current distribution and composition of nearshore benthic communities using intensive surveys and recent aerial photographs. Next, historic aerial photographs were used to construct a complete time series of maps at multiple sites within the study area. The nature of changes within nearshore benthic communities at those sites was investigated. Nutrient samples were also collected near the time series sites to characterize the nutrient regimes of nearshore benthic communities (Figure 10.2). Finally, all project data and available countywide land use activity data were incorporated into a GIS database. Database queries and spatial analyses were conducted to explore relationships between land use activities, nearshore nutrient regimes, and nearshore benthic communities in the Florida Keys.

FIGURE 10.2
BENTHIC SAMPLING LOCATIONS NEAR MARATHON



The first working hypothesis, that nearshore benthic communities and their associated nutrient regimes exhibit spatial or temporal variation throughout the Florida Keys, was conclusively proven (Section 11). Both nearshore benthic communities and their associated nutrient regimes do exhibit spatial variation throughout the Florida Keys. However, nearshore benthic communities exhibited very little temporal variation through the past 40 years, even in the face of tremendous land development in the Florida Keys. The results provided little evidence to support the hypothesis that there is a significant relationship between human land use activity and spatial or temporal variation of nearshore benthic communities and their associated nutrient regimes throughout the Florida Keys. Results indicate that substrate, not land use, is the most important factor associated with benthic community distribution and composition (Section 11). Two modeling approaches identified potential relationships between a few individual taxa, taxa groups, nutrient parameters, and land use, but very few of these relationships are significant throughout the Florida Keys.

10.2.6 Water Quality in Canals and Other Confined Waters

Initially, and in line with its regional scope, the FKCCS explored the use of a circulation model to address the fate of pollutant loads as they are discharged into the waters of the FKNMS. Due to the absence of Keys-specific circulation models, a GIS-based dispersion approach was used. However, lack of reliable data prevented the development of a robust modeling approach.

Subsequently, efforts were initiated to address the relationship between land-generated loads and water quality in canals. These efforts responded to the request of stakeholders, such as the South Florida Water Management District, the EPA, and Monroe County. The Canal Impact Assessment Tool (CIAT) is now in progress, and will focus on the impacts of wastewater effluents and stormwater discharges to the canal systems. The model will not attempt to predict actual water quality in canals, but will address the anticipated changes in loads and resulting water quality from different land use and treatment scenarios.

10.3 Direct Human Impacts on Marine Resources

Residents and tourists alike use the expansive waters of the FKNMS for boating, snorkeling, diving, and fishing. Each of these activities put people in direct contact with environmental resources and may significantly affect them. The study team's research focused on four types of direct impacts: propeller scarring, boat groundings, snorkeling and diving impacts, and fishing pressure. The main objective was to determine a quantitative and spatial relationship between land development activities, people, and impacts to the resources.

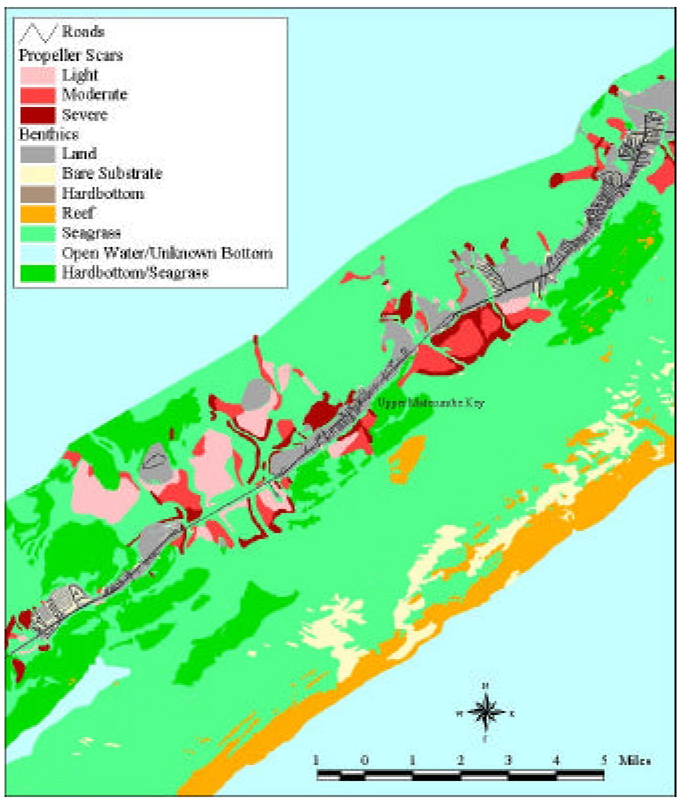
10.3.1 Propeller Scarring in Seagrasses and Boat Groundings on Coral Reefs

Initially, efforts concentrated in quantifying the volumes and sources of boat traffic within the study area. A review of the literature revealed that no comprehensive boat traffic study existed for the Florida Keys (Leeworthy 1998, Stolpe 1998, Matthews and Donovan 1992, FKNMS 1996; Kruer 1993).

Subsequently, the contractor evaluated aerial survey data for boat usage from both FMRI and the National Marine Fisheries Service (NMFS). The NMFS Miami Laboratory, in conjunction with the United States Coast Guard Miami Air Station, has monitored vessel activity in the Sanctuary from 1992 to present. FMRI aerial fly-over/surface survey data, collected from June 1992 through August 1993, represents the most rigorous attempt to estimate utilization of the FKNMS to date. However, the FMRI survey includes data for only one year, which prevents any correlation analysis to development in the Florida Keys. In addition, Hurricane Andrew hit south Florida during the FMRI survey period. The NMFS survey data, though collected for nine years, does not measure the total number of boats. Therefore, neither dataset proved appropriate for establishing a connection between population and the number of boats utilizing the FKNMS.

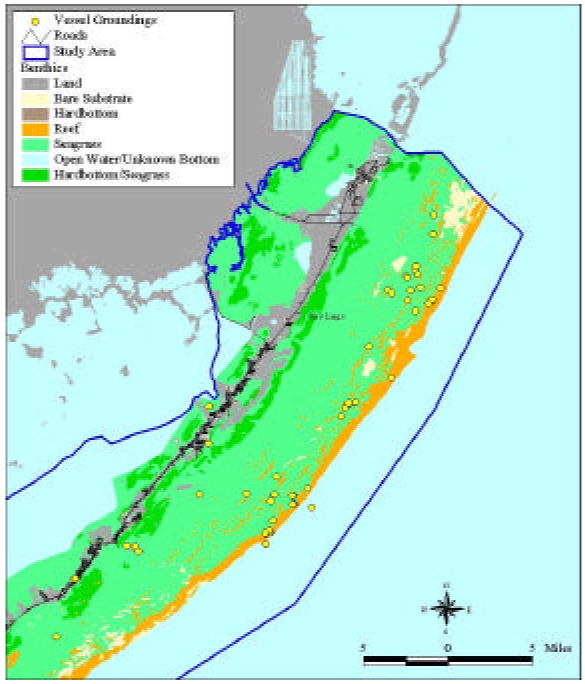
FMRI developed a seagrass scarring map (Sargent et al. 1995, see Figure 10.3) that classifies scars as light, moderate, or severe. Multiple regression analysis showed no significant correlation between the distribution of scars and a series of development surrogates, including development status of the nearest shore, location of marinas and boat ramps, location of navigational aids, and location of channels. The distribution of scarred seagrass areas was only correlated with distance from shore (independently of shoreline type) and water depth. The conclusion was that, as expected, seagrass scarring occurs mainly in nearshore, shallow water.

FIGURE 10.3
PROPELLER SCARS MAPPED IN THE UPPER MATECUMBE AREA



In addition, FMRI maintains a spatial boat groundings database (Figure 10.4). As expected, boat groundings occur mainly near reef areas, and are more likely to occur in popular reef destinations.

FIGURE 10.4
FMRI BOAT GROUNDINGS DATA IN THE UPPER KEYS



10.3.2 Snorkeling and Diving Impacts on Coral

Recreational SCUBA diving causes damage to reefs at exponentially increasing rates as diving intensity increases (Hawkins and Roberts 1992). The total dive site area in the Florida Keys is 217 nautical square miles (Kearney and Centaur 1991). A third of the tourists in the Keys participate in scuba diving or snorkeling (Monroe County Tourist Development Council 1997-2001). Nearly 90 percent of the significant dive spots are located in the upper Keys and are popular because of their accessibility and the number of dive operations available.

A Florida study showed divers touched coral heads an average of seven times during a 30-minute interval, while five percent of divers have more than 20 incidents per 30-minute dive (Tagle 1990). Snorkellers generally stand on corals and stir up large amounts of sediment, but they usually have fewer contacts than scuba divers. Scuba divers generally touch corals when pushing off the substrate and when finning. Indicator species considered for diver damage were branching corals as opposed to massive corals (Paryente et al. 1999, Rouphael and Inglis 1995, Hawkins and Roberts 1992). However, sanctuary-wide coral monitoring data exists only for 4 years, rendering identification of long-term changes in coral densities difficult (Jaap et al. 2001).

Diver damage to corals is unlikely to have major consequences for local coral populations, but may be substantive enough to affect the aesthetic appeal of the sites (Rouphael and Inglis 1995).

10.3.3 Recreational Fishing

Recreational fishing is an integral part of life in the Florida Keys. The study team spent a considerable amount of effort researching the relationship between development, population, recreational fishing effort and the status of the fisheries. The primary means by which development is likely to impact fisheries in the Florida Keys include direct fishing pressure, production of pollutants affecting fisheries, and destruction of essential habitat. Commercial fisheries were not rigorously considered because commercial fishing pressure is largely independent of residential and tourism development patterns. The number of commercial vessels in the Keys has remained almost constant since the early 1960s (Bohnsack et al. 1994).

Catch per unit effort (CPUE) commonly provides a measure of stock abundance, but other factors may also influence catch. Bohnsack 1994 point out that "better data are particularly needed for recreational fisheries although the task will be complex considering the number of participants, various modes of fishing (private boat, shore, bridges, guide boats, headboats, charter boats), the various species targeted (e.g., inshore flats, reefs, offshore trolling), and the various goals of individual participants (trophy fish, food, excitement, catch-and-release, 'just catch something')." Further complicating CPUE, are the changes due to a rapidly growing fishing power per vessel (Mace 1997). As a result, "catch per boat day" has a much different meaning than ten or even five years ago, rendering year-to-year comparisons questionable. CPUE evaluation is also complicated by the fact that guided services, including guide, charter, and head boats, are adept at altering fishing targets when CPUE weakens, in order to provide satisfaction to clients. For all these reasons, available CPUE data are difficult to use to predict impacts of land development activities.

Ault (1997) suggested that the Florida Keys reef fish stocks exhibit classic overfishing patterns with more vulnerable species being progressively depleted (citing Munro and Williams 1985 and Russ and Alcala 1989), and that several reef fish stocks are overfished according to NOAA definitions (citing Rosenberg et al. 1996). However, these conclusions do not clarify quantitative relationships between land development and fishing pressure. A recent report by the FKNMS reported higher densities of several fish species occurring in no-take zones of Sanctuary Preservation Areas than in uncontrolled fishing areas, but this information was not quantitatively related to fishing pressure (NOAA 1998).

Evaluations of existing recreational fishery datasets sought to uncover potential trends with respect to development. Indicator species were selected for analysis and grouped into nearshore and offshore species. "Nearshore species" included the yellowtail snapper (*Ocyurus chrysurus*), gray snapper (*Lutjanus griseus*), white grunt (*Haemulon plumieri*), black grouper (*Mycteroperca bonaci*), gag grouper (*Mycteroperca microlepis*), red grouper (*Epinephelus morio*) and spiny lobster (*Panulirus argus*). "Offshore species" included king mackerel (*Scomberomorus cavalla*), dolphin (*Coryphaena hippurus*), and greater amberjack (*Seriola dumerili*). Two species were considered but not included in the analysis: pink shrimp (*Penaeus duorarum*) is not part of the recreational fishery, and mutton snapper (*Lutjanus analis*) is typically caught incidentally rather than targeted by anglers (Mueller 2001).

FMRI and the NMFS Beaufort Laboratory provided datasets for this analysis, and assisted in the preparation and analysis of the marine recreational fisheries survey and headboat data. The FMRI Marathon laboratory provided recreational lobster data. The following is a discussion of the various survey methodologies and results.

NMFS conducts annual Marine Recreational Fisheries Statistics Surveys (MRFSS) to obtain estimates of participation, effort, and catch by recreational anglers in the United States. Data are collected in two independent surveys: a telephone survey of households in coastal counties, and an intercept (i.e., interview) survey of anglers at fishing access sites such as boat ramps and bridges (Table 10.3).

Telephone and intercept surveys collect data on recreational fishing effort, and information regarding species identity, number, fish weights and lengths, respectively. Data from the two independent surveys are combined to produce estimates of fishing effort, catch, and participation. Using data from both surveys, marine recreational fishing estimates (not including shellfishing) are calculated for six two-month periods (waves) per year.

TABLE 10.3
TYPES OF DATA BY THE MRFSS SURVEY METHODS

Intercept Survey	Telephone Household Survey
Number, weights and lengths of fish caught by species	Presence of marine recreational anglers in the household
State and county of residence	Number of anglers per household
Avidity level - trips per year	Fishing trips in 2-month period
Mode of fishing	Mode of each trip
Primary area of fishing	Location (county) of each trip

The Center for Coastal Fisheries Habitat Research (CCFHR), sponsored by the National Ocean Service and NMFS, has surveyed the headboat recreational fishery in the Florida Keys since 1978. Headboats, also referred to as “party” boats, are large vessels where recreational anglers pay “by the head” to fish. Survey data consists of logbook records and length measurements of landed fish. Effort is measured in “angler days” rather than the total number of anglers that have fished on headboats, calculated as follows:

$$\text{Angler Days} = \text{Number of anglers} * \text{K-factor}$$

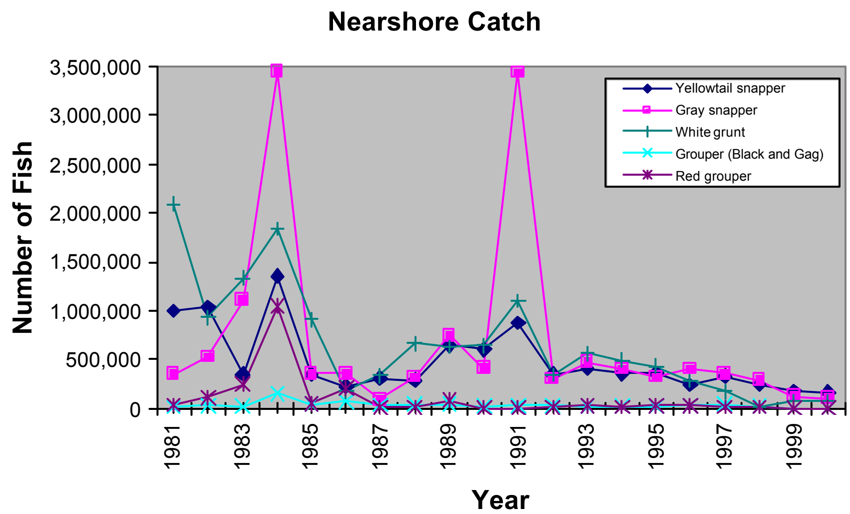
where the K-factor refers to the type of trip, such as, 1/2 day, 3/4 day, full day, or overnight. For example, the K-factor for a 1/2-day trip is 0.5 and for a full day trip is 1.0.

FMRI collects recreational lobster data from a mail-survey of lobster license holders twice annually. Each survey questions recipients about their activities and resulting catch for the two-day lobster mini-season and first month of the regular lobster fishing season. The MRFSS, headboat and recreational lobster survey data were used for a comprehensive regional analysis of the Florida Keys recreational fisheries. Via the federal MRFSS and Headboat Survey data, trends in recreational fishing were analyzed for Monroe County between 1981 and 2000. Lobster data were analyzed for the Florida Keys for the years 1993 through 2000. Trends analyzed include:

- **Catch.** According to these data, total catch for nearshore species has decreased over time while catch for the offshore species has increased over time (Figure 10.5). General trends for each dataset are shown on those graphs with trend lines. Whereas the reduction of nearshore catch may be correlated with a decrease in nearshore fish populations, the observed rise in the offshore catch rate could be indicative of other factors, rather than an actual increase in the offshore fish populations. Technological advances in fishing lines and electric reels, tracking devices such as GPS, and increased boating power could have increased catch in offshore species.
- **Size Class.** Mean length of harvest is an important indicator of age class of the catch, since it is assumed that length is proportional to age. Mean length of both nearshore and offshore species has increased over time (Figure 10.6).
- **Effort.** Recreational fishing participation has increased over time. However, the total number of recreational fishing trips has decreased while the number of registered boats has steadily increased (Figure 10.7).
- **Lobster Season.** The number of lobsters caught during both the regular season and the mini-season has increased only slightly over the past seven years. The total number of participants for the regular season has decreased while the total number of participants for the mini-season has slightly increased (Figure 10.8). The proportion of participants from the West Coast of Florida that participate in the two-day mini-season is increasing.
- **Catch per Unit Effort.** Effective fishing effort has changed over time with increased participants and improved technology. Bohnsack et al. (1994) reported that, in Monroe County, CPUE for all grouper species (Serranidae) has declined since the mid 1980's, and that pink shrimp (*Penaeus duorarum*) declined earlier that same decade. Stone crab (*Menippe mercenaria*) and spiny lobster (*Panulirus argus*) have shown significant changes in CPUE (Bohnsack et al. 1994).

  For six of the eight indicator species, CPUE has declined over the last 20 years, although not significantly (Figure 10.9). CPUE for dolphin has remained unchanged and increased for the greater amberjack; none of these correlations were significant. All CPUE estimates for the referenced species were provided by Dr. Bob Mueller at FMRI and calculated using MRFFS data from 1981 through 2000.

FIGURE 10.5
NEARSHORE AND OFFSHORE CATCH (NUMBER OF FISH CAUGHT OVER TIME)



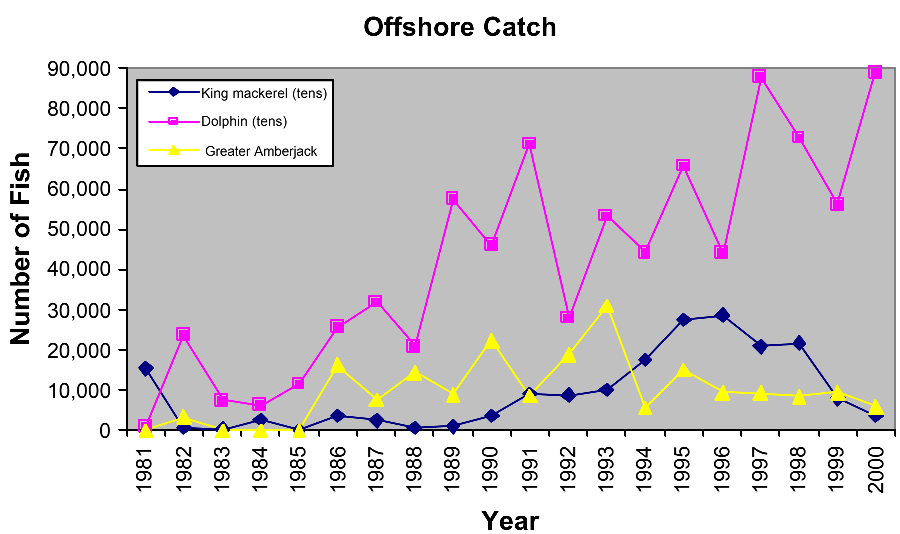
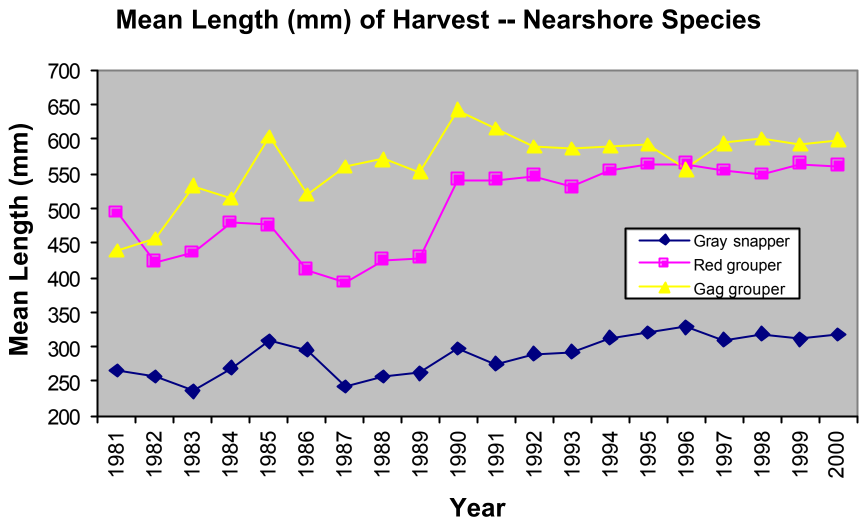


FIGURE 10.6
MEAN LENGTH OF HARVEST (MM) - NEARSHORE AND OFFSHORE SPECIES



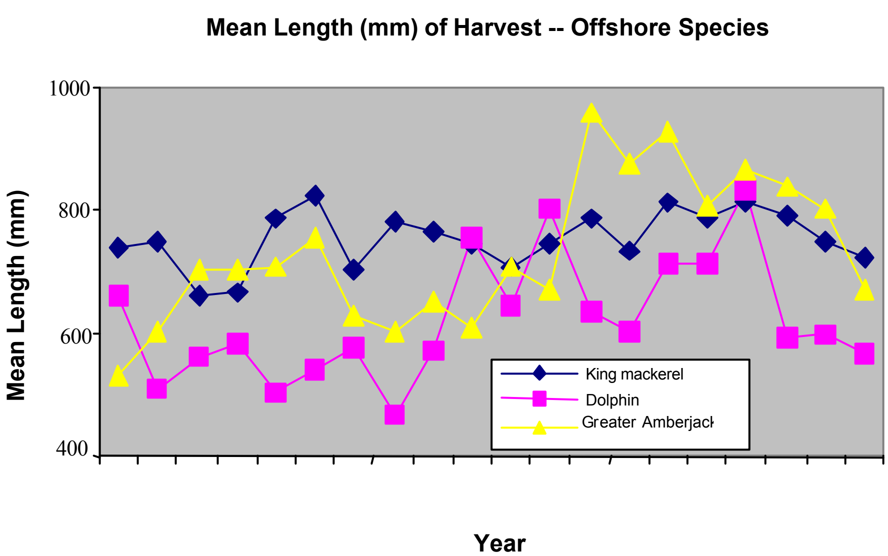
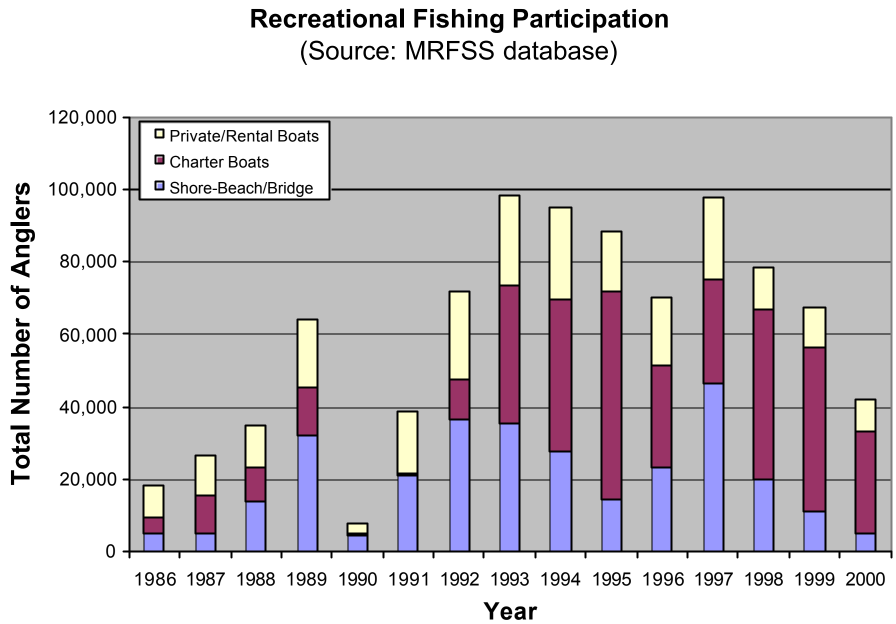


FIGURE 10.7
RECREATIONAL FISHING PARTICIPATION AND EFFORT



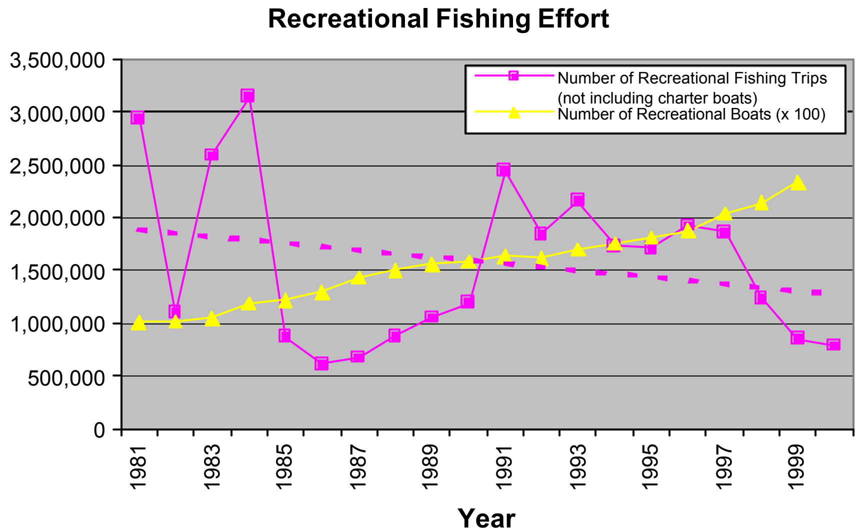
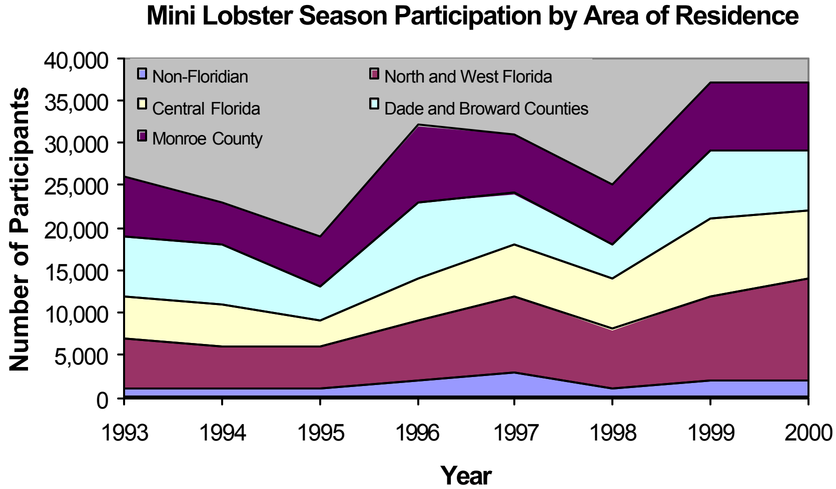
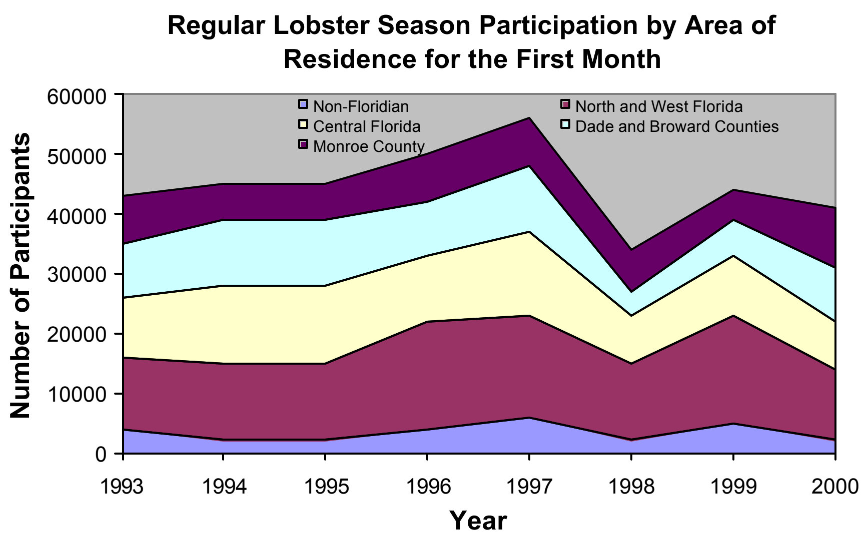


FIGURE 10.8
LOBSTER SEASON AND MINI-SEASON CATCH AND PARTICIPATION





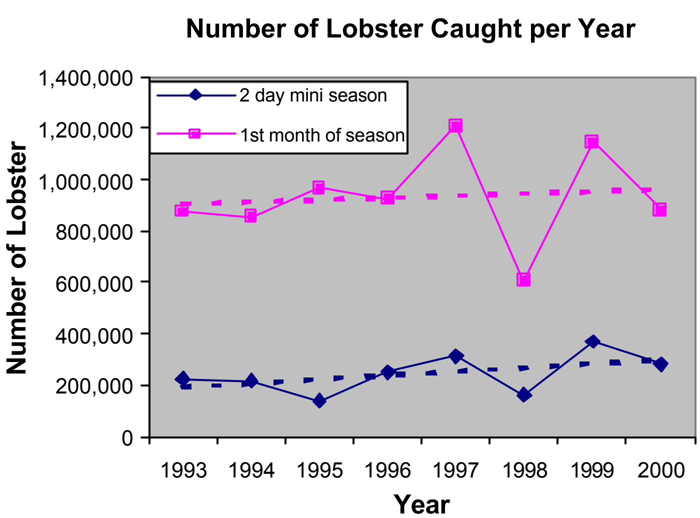


FIGURE 10.9
CATCH PER UNIT EFFORT (NUMBER OF FISH CAUGHT PER TRIP)
BY SPECIES OVER TIME (NMFS MRFSS DATA)

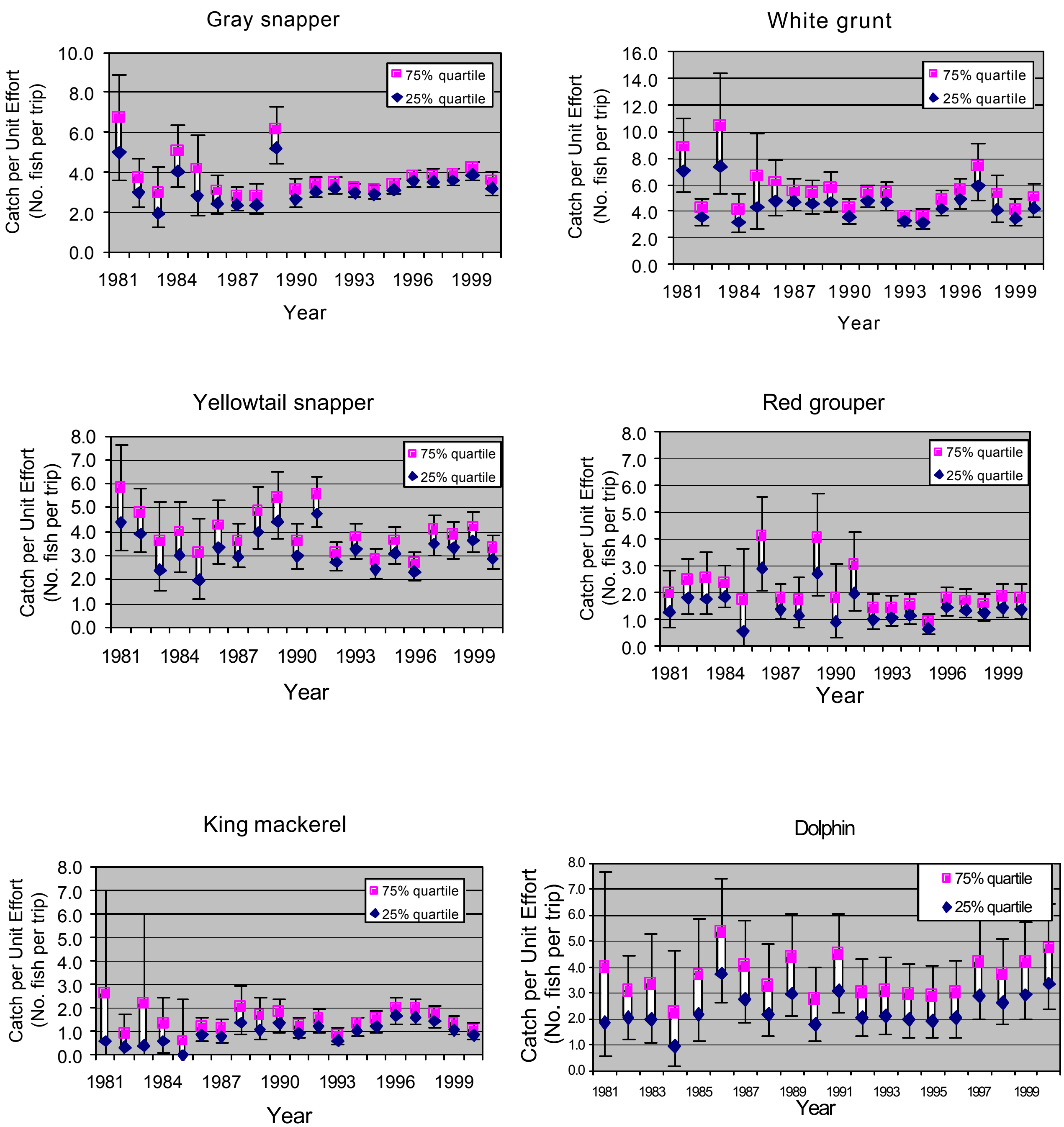


FIGURE 10.9 (CONTINUED)
CATCH PER UNIT EFFORT (NUMBER OF FISH CAUGHT PER TRIP)
BY SPECIES OVER TIME (NMFS MRFSS DATA)